98P 3172 88

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : 0 492 899 A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number : 91311519.2

(22) Date of filing : 11.12.91

(51) Int. Cl.5 : G21C 9/012

(30) Priority : 20.12.90 US 633747

(43) Date of publication of application :
01.07.92 Bulletin 92/27

(84) Designated Contracting States :
CH DE ES IT LI NL SE

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(54) **Passive hydraulic vacuum breaker.**

(57) The present invention is directed to a nuclear reactor facility wherein a nuclear reactor pressure vessel (RPV) is housed within an annular sealed drywell (14), an annular sealed wetwell (18) houses said drywell, a pressure suppression pool (28) of liquid is disposed in said wetwell and is connected to said drywell by submerged vents (30a, 30b, 30c), a condenser line connects said drywell (14) to an isolation condenser, and a bleedline (42) from said isolation condenser is connected to said pool and terminates under the surface of said pool. The improvement of the present invention comprises a liquid reservoir (60) disposed in said drywell (14) and a standpipe (64) disposed in said wetwell (18). The reservoir and the standpipe are connected by a duct (66) which is located below the surface of said reservoir a distance, D. The area of the reservoir is at least 25 times larger than the area of said standpipe.

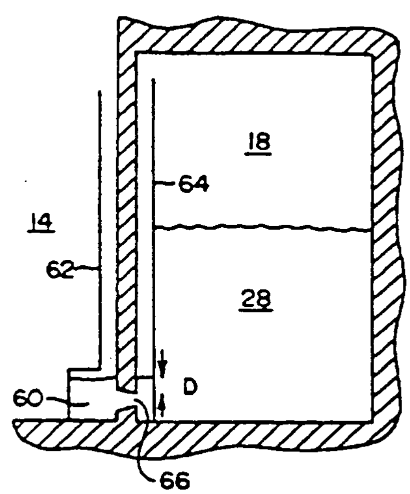

FIG. 3

EP 0 492 899 A1

Background of the Invention

The pr sent invention relates to nuclear boiling water reactors (BWRs) and more particularly to containment utilizing lateral vents.

With respect to safety aspects of BWRs, the most serious credible reactor accident is in general conceived as a rupture of the reactor pressure vessel (RPV) or of a major coolant line connected to the vessel. Such an occurrence is known as a loss of coolant accident (LOCA). To prevent the release of toxic products resulting from such an accident, the RPV is placed within a series of containment structures. BWRs have a primary and a secondary containment structure. The primary containment vessel consists of a drywell and a wetwell. In a majority of BWRs operating in the 1970's, the drywell is a steel pressure vessel shaped like an electrical light bulb. It is designed for a pressure of 350 kPa(g) and is tested above 420 kPa(g). The steel vessel is enclosed in a thick, reinforced concrete structure which provides the mechanical strength and also serves as a radiation seal. The drywell contains the reactor and the coolant recirculation pumps. The secondary containment vessel or shield building commonly is a rectangular structure of reinforced concrete about 1.0 m thick.

In more recent BWRs, the drywell is a concrete cylinder with a domed top. The wetwell is an annular chamber in which the water is retained by an interior rear wall and by the steel cylinder that is the primary containment structure. Connection between the drywell and the wetwell is provided by a number of horizontal cylindrical vents in the lower part of the drywell wall. A reinforced concrete shield building constitutes the secondary containment.

During a LOCA, the steam released by the flashing of the coolant water would be forced into the water of the wetwell and be condensed, thereby lowering the temperature and pressure of the drywell atmosphere. Hence, the wetwell commonly is referred to as the pressure suppression pool.

The development of vertical layer lateral vents for the pressure suppression pool is disclosed in U.S. Pat. No. 3,115,450. Such lateral vent concept allows a gradual increase in the air clearing load to the pressure suppression pool. In a BWR currently under design known as the "simplified boiling water reactor", and possibly larger BWRs with passive features, there will be an advantage in using the heat sink offered by the several millions of kilograms of water comprising the suppression pool for the long term cooling f the containment. In the SWBR, long term heat removal is assured by the isolation condensers, but they require some bleeding to the pressure suppression pool to remove non-condensabl gases that can otherwise accumulate in the isolation condensers, reducing their heat transfer capabilities. The outlet of this bleedline must be less submerged in the pressure suppression pool than the elevation of the uppermost horizontal vent on the drywell side of the drywell-wetwell boundary. This feature allows the pressure difference between the drywell and wetwell to drive any steam plus non-condensible mixture through the isolation condensers and to drive any residual steam vapor plus non-condensibles downstream into the wetwell. The pressure in the drywell of the BWR containment may become sub-atmospheric when cold water is injected into the RPV and the RPV overflows or the water spills out through the break. The containment liner, usually made of thin steel plates welded together and anchored to the containment wall, will not withstand negative pressures and will fail. Conventionally, a vacuum breaker is installed between the wetwell and the drywell which consists of a check valve which opens at a predetermined pressure differential, e.g. 4 kPa. However, there is a potential danger that this check valve will stay open. The envisaged design of the isolation condenser of the SBWR is dependent upon a higher pressure in the drywell than in the wetwell in order for non-condensibles to be transported by the bleedline to the wetwell. There is no pressure differential between the drywell and the wetwell with a vacuum breaker valve stuck in an open position. Also, there is no head between the isolation condenser and the wetwell, and correspondingly, no transport of non-condensibles to the wetwell. Gas blanketing of the isolation condenser cannot be excluded, as the non-condensibles accumulate in the isolation condenser. This will result in insufficient heat removal with consequent possible failure of the containment.

Broad Statement of the Invention

The present invention is directed to a nuclear reactor facility wherein a nuclear reactor pressure vessel (RPV) is housed within an annular sealed drywell, an annular sealed wetwell houses said drywell, a pressure suppression pool of liquid is disposed in said wetwell and is connected to said drywell by submerged vents, a condenser line connects said drywell to an isolation condenser, and a bleedline from said isolation condenser is connected to said pool and terminates under the surface of said pool. The improvement of the present invention comprises a liquid reservoir disposed in said drywell and a standpipe disposed in said wetwell. The reservoir and the standpipe are connected by a duct which is located below the surface of said reservoir a distance, D. The area of the reservoir is at least 25 times larger than the area of said standpipe.

Advantages of the present invention include a hydraulic vacuum breaker that fulfills the functions of conventional mechanical vacuum breakers. Another advantage is a hydraulic vacuum breaker that operates in a passiv manner, i.e. has no moving parts to

fail. A further advantage is a hydraulic vacuum breaker that is amenable for installation within th design parameters of nuclear r actors, especially . These and other advantag s will be readily apparent to those skilled in the art based on the disclosure contained herein.

Brief Description of the Drawings

Fig. 1 is a simplified cross-sectional elevational view of a reactor building showing the nuclear reactor vessel and associated containment;
Fig. 2 is a simplified schematic showing the steam mixture pathway during blowdown; and
Figs. 3-5 are exploded views of the drywell/wetwell interface connected by the inventive passive hydraulic vacuum breaker during three different modes of operation.
The drawings will be described in detail below.

Detailed Description of the Invention

Referring initially to Fig. 1, reactor 10 can be seen to be housed within reactor shield wall 12. In turn, such assembly is located in drywell 14 which is formed by drywell wall 16. Annular drywell 14, in turn, is housed within annular wetwell 18 which is defined by containment 20. Shield building 22 completes the reactor building. Disposed overhead is upper pool 24 which, in turn, is surmounted by containment space 26 formed in the dome of shield building 22. Annular pressure suppression pool 28 is contained within wetwell 18 and connets drywell 14 and wetwell 18 via vertically-stacked, laterally-opening submerged vents, e.g. vents 30a-30c.

With respect to implementation of the vertical layered lateral vent arrangement set forth at Fig. 1, reference is made to Fig. 2. Reactor vessel 10 is seen to be housed within drywell 14 which is in communication with isolation condenser 32 via line 34. Steam and non-condensible mixture can flow in the direction of arrow 36 via line 34 into isolation condenser 32 that is disposed within upper pool 24. Steam can be exhausted via vent 38. Condensate is returned from isolation condenser 32 to vessel 10 via line 40. Bleed line 42 runs from isolation condenser 32 to pressure suppression pool 28 with its end submerged below surface 44 of pool 28, but above the level of upper vent 30a.

In a postulated large LOCA, steam will be released from reactor vessel 10 and this will increase the pressure in drywell 14. This pressure will, after a short time period, become so great that uppermost vent 30a will clear and steam will be injected into pool 28 housed in wetwell 16. Such steam mixture will mix with the water in pool 28 and lift the water up before being condensed. A short while later, the second vent clears and the process is r peated. Finally, the third vent clears. The staggered clearing will prevent the occurr nce of a water hamm r phenomenon with attendant possible damage to pr ssure suppression pool 28.

After depressurization of vessel 10, cold water will be injected into the vessel and after a longer period of time, this water will commence to boil. In presently designed SBWRs, steam emanating from vessel 10 will be condensed by isolation condenser 32 and the condensate returned to vessel 10 via line 40. As the vessel is assumed to be in open contact with drywell 14, it is possible that non-condensibles will flow with the steam to isolation condenser 32 and eventually accumulate there. The heat transfer of condenser 32 is reduced greatly in the presence of non-condensibles. In order to avoid significant deterioration of condenser 32, bleedline 42 runs to pool 28. A small fraction of steam also will be transported to suppression pool 28 with the non-condensibles and this steam will condense and heat up the layer of water above end 46 of line 42. The h at capacity of this layer of water is finite and the pressure in wetwell 18 above pool 28 will be given by the amount of non-condensibles in the space and the partial pressure of steam corresponding to the temp rature of the uppermost water layer in pool 28.

Referring to Figs. 3-5, the inventive hydraulic vacuum breaker is shown in three different possible conditions. Referring to Fig. 3 initially, liquid reservoir 60 is seen to be located in drywell 14. Standpipe 62 optionally can be used to insure that the liquid in reservoir 60 does not accidentally leak into drywell 14. Standpipe 64 is disposed in wetwell 18 and is connected to reservoir 60 via vent 66. The static head of reservoir 60 is determined by the distance, D, of the duct located below the surface of reservoir 60. The condition depicted at Fig. 3 is a normal operating condition of the nuclear reactor facility.

Referring to Fig. 4, the hydraulic vacuum breaker during blowdown is depicted. During blowdown, the pressure in drywell 14 is expected to increase to an extent that the liquid in reservoir 60 is displaced downwardly at least a distance D. The water level will rise in standpipe 64 during the blowdown phase aft r an accident has happened. No bypass will occur, provided the pressure differential between the drywell and the wetwell does not exceed the static head in standpipe 64. For a relatively short period in the initial phase of the blowdown, the pressure differential may exceed this head due the accelerated pressure drop and the pressure drop across the penetration. Thereafter, the water will flow back from standpipe 64 to reservoir 60.

Referring to Fig. 5, an "open" condition is shown. In this condition, air will flow from wetwell 18 to drywell 14 after reversal of the pressure differential therebetween and when this differential has exceeded the static head, D. Thus, the vacuum in drywell 14 will be

broken and the pressure "equalized" to prevent containment failure.

As to materials of construction, preferably all components are manufactured from materials appropriate for their use within a nuclear BWR. Further, it will be appreciated that various of the components shown and described herein may be altered or varied in accordance with the conventional wisdom in the field and certainly are included within the present invention, provided that such variations do not materially vary within the spirit and precepts of the present invention as described herein.

Claims

1. In a nuclear reactor facility wherein a nuclear reactor pressure vessel (RPV) is housed within an annular sealed drywell, an annular sealed wetwell houses said drywell, a pressure suppression pool of liquid is disposed in said wetwell and is connected to said drywell by submerged vents, a condenser line connects said drywell to an isolation condenser, a bleedline from said isolation condenser is connected to said pool and terminates under the surface of said pool, the improvement which comprises:

   a liquid reservoir disposed in said drywell and a standpipe disposed in said wetwell, said reservoir and said standpipe being connected by a duct which is located below the surface of said reservoir a distance D, the area of said reservoir being at least 25 times larger than the area of said standpipe.

2. The facility of claim 1 wherein D is 0.4 m.

3. The facility of claim 1 wherein said liquid comprises water.

4. The facility of claim 1 wherein a retaining wall extends above the surface of said reservoir in said drywell.

5. The facility of claim 1 wherein gas in said wetwell will flow to said drywell for negative pressure differentials of greater than about 4 kPa.

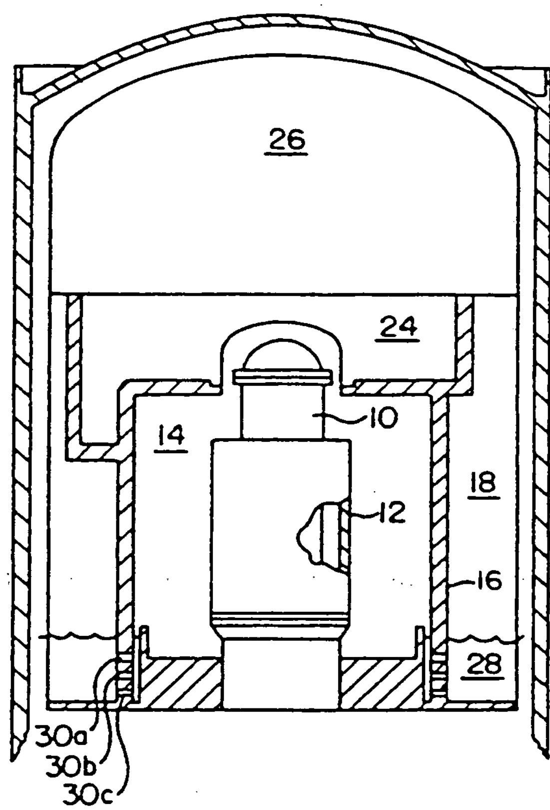
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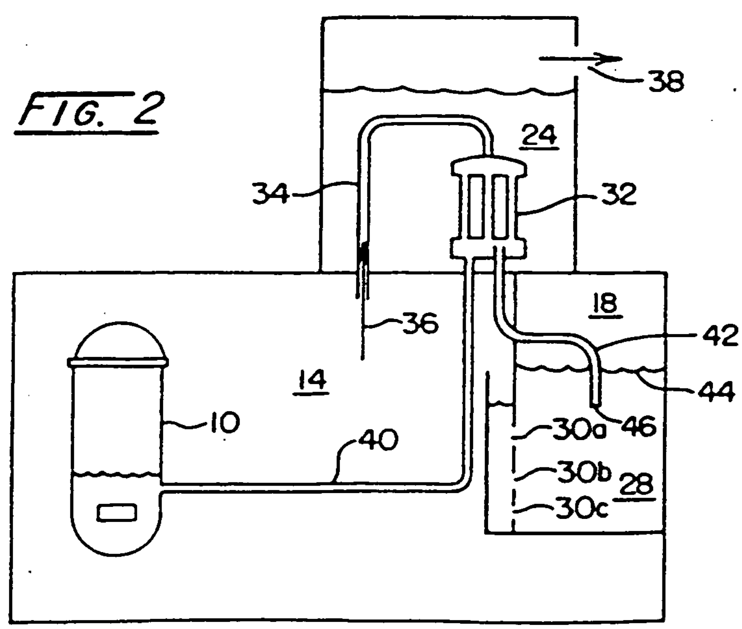
FIG. 1

FIG. 2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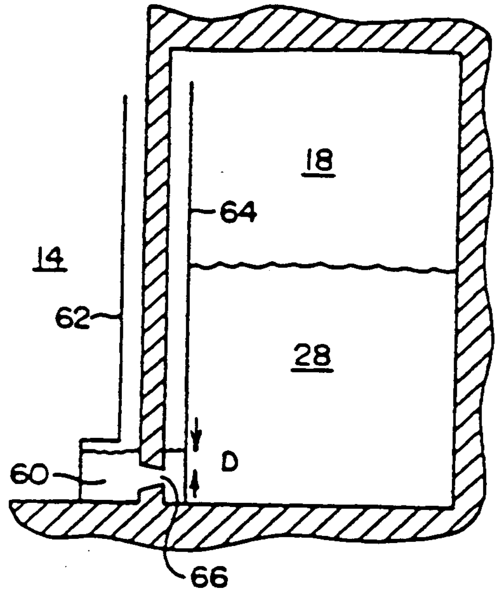

FIG. 3

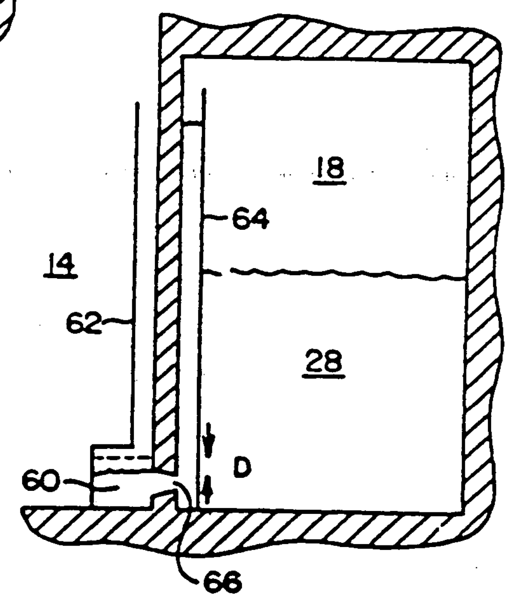

FIG. 4

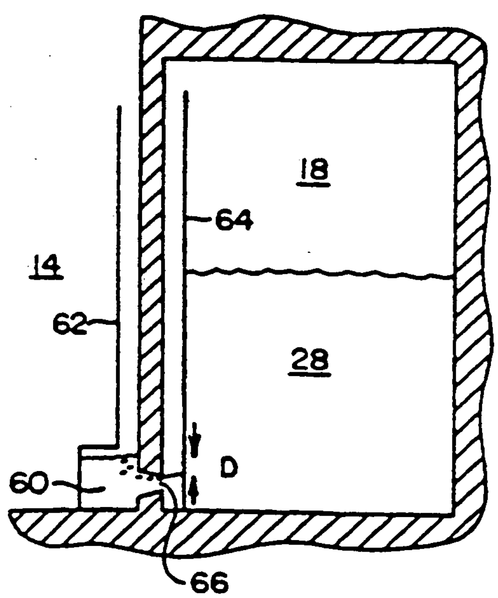

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number

EP 91 31 1519

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	US-A-4 950 448 (PERNG-FEI GOU) * column 3, line 49 - column 4, line 4; figure 1 *	1,3	G21C9/012
A	EP-A-0 397 162 (HITACHI) * column 7, line 50 - column 8, line 2; figures 1,2 *	1,3	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			G21C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	12 MARCH 1992	JANDL F.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P0401)

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